

COMMUNICATION SCIENCES  
AND  
ENGINEERING



## XVIII. OPTICAL PROPAGATION AND COMMUNICATION

### Academic and Research Staff

Prof. Robert S. Kennedy  
Prof. Jeffrey H. Shapiro

Prof. Cardinal Warde  
Dr. Horace P. H. Yuen

### Graduate Students

Roy S. Bondurant  
Marcel F. Coderch  
Paul J. Curlander  
William P. Jaeger  
Peter W. Kinman

James S. Linnell  
Jesus A. Machado-Mata  
Nam-Soo Myung  
Jun Nakai  
Woo Hyun Paik

David M. Papurt  
Warren S. Ross  
Diane C. Simmons  
Mahmoud Tebyani  
Gregory L. Timp

The broad objectives of our program are to (i) formulate propagation models for important optical channels from the underlying physical processes, (ii) determine the fundamental limits on detection and communication performance that can be realized with these channels, (iii) develop techniques for optical detection and communication which achieve or approach these limits, and (iv) establish, by means of experiment, the validity of the theoretical results and guide their further development.

### 1. QUANTUM COMMUNICATION THEORY

National Aeronautics and Space Administration (Grant NGL 22-009-013)  
Joint Services Electronics Program (Contract DAAG29-78-C-0020)

Horace P. H. Yuen, Jeffrey H. Shapiro, Robert S. Kennedy

The long-range goal of this investigation is to realize improved optical communication, detection, and estimation in the space environment. Such improvement may be possible through the use of quantum measurements (optical receivers) that are superior to those now considered and the use of quantum states other than coherent states. Our major goal during the next year is to design an experiment which will demonstrate that the desired quantum states, called two-photon coherent states, can be produced.

During the past year, a series of papers which resolve many of the questions concerning the propagation and detection of quantum fields have been prepared and published by Professor Shapiro and Dr. Yuen.<sup>1-3</sup> Also, in his doctoral research, Mr. Curlander has shown that, for digital communication with error probability as a performance measure, the optimum quantum receiver for either pure coherent states or pure two-photon coherent states is not markedly superior to the performance that can be achieved with homodyning. This resolves a question that has persisted for some time.

The other work in this area has been the design of an experiment to verify that two-photon coherent states can be produced. These states are interesting for communication because they allow the total quantum noise required by the uncertainty principle to

## (XVIII. OPTICAL PROPAGATION AND COMMUNICATION)

be divided unequally between the quadrature components of the field, thereby permitting marked improvement in the attainable performance. The experiment has been designed and a means of performing it is now being sought.

### References

1. H. P. Yuen and J. H. Shapiro, "Optical Communication with Two-Photon Coherent States – Part I: Quantum State Propagation and Quantum Noise Reduction," IEEE Transactions on Information Theory, Vol. IT-24, No. 6, pp. 657-668, November 1978.
2. J. H. Shapiro, H. P. Yuen, and J. A. Machado-Mata, "Optical Communication with Two-Photon Coherent States – Part II: Photoemissive Detection and Structured Receiver Performance," IEEE Transactions on Information Theory, Vol. IT-25, No. 2, pp. 179-192, March 1979.
3. H. P. Yuen and J. H. Shapiro, "Optical Communication with Two-Photon Coherent States – Part III: Quantum Measurements Realizable with Photoemissive Detectors," submitted to IEEE Trans. Inform. Theory.

## 2. IMPROVED LOW-VISIBILITY COMMUNICATION

National Science Foundation (Grant ENG78-21603)

U. S. Army Research Office – Durham (Contract DAAG29-77-C-0048)

Robert S. Kennedy, Jeffrey H. Shapiro, Cardinal Warde

This investigation, which is carried out jointly with the M. I. T. Center for Materials Science and Engineering, is concerned with the performance of terrestrial communication systems under conditions of low visibility. Our aim is to determine the extent to which performance can be improved through appropriate system design, and to develop the devices for achieving this improvement. The potential for improvement resides in the energy and information contained in the scattered component of the received field.

The initial goal in the program has been to experimentally determine the magnitudes of key propagation parameters so that a useful theoretical model of the propagation can be developed through judicious approximation. Earlier measurements at wavelengths of 0.69  $\mu\text{m}$  and 2.06  $\mu\text{m}$  over our 13-km propagation path have now been augmented with measurements at wavelengths of 0.25  $\mu$ , 0.27  $\mu\text{m}$ , 0.53  $\mu\text{m}$ , and 1.06  $\mu\text{m}$ .<sup>1</sup> Also, a series of measurements in fog were made over a 1000-ft path at a wavelength of 0.25  $\mu\text{m}$  in Lubec, Me.<sup>2</sup> During the coming year we will make further fog measurements in Eastport, Me., and will begin to supplement our 13-km observations with measurements over a path of approximately 4 or 5 km. We also expect to increasingly shift our attention from the collection of data to the development of a useful multiple scatter propagation model.

(XVIII. OPTICAL PROPAGATION AND COMMUNICATION)

References

1. W.H. Paik, M. Tebyani, D.J. Epstein, R.S. Kennedy, and J.H. Shapiro, "Propagation Experiments in Low-Visibility Atmospheres," Appl. Opt. 17, 889-905 (1978).
2. W.S. Ross, "An Investigation of Atmospheric Optically Scattered Non-Line-of-Sight Communication Links," U.S. Army Research Office Final Report, Contract DAAG29-77-C-0048, September 26, 1978, 54 pages.

